Cardio-pulmonary fitness test by ultra-short heart rate variability

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ABSTRACT

Objectives: It is known that exercise induces cardio-respiratory autonomic modulation. The aim of this study was to assess the cardio-pulmonary fitness by ultra-short heart rate variability. **Materials and Methods:** Study population was divided into 3 groups: Group-1 (n = 40) consisted of military sports man. Group-2 (n = 40) were healthy age-matched sedentary male subjects with normal body mass index [BMI = 19 - 25 kg/m^2). Group-3 (n = 40) were healthy age-matched obese male subjects [BMI > 29 kg/m^2). Standard deviation of normal-to-normal QRS intervals (SDNN) was recorded over 15 minutes. Bruce protocol treadmill test was used; and, maximum oxygen consumption (VO_2max) was calculated. **Results:** When the study population was divided into quartiles of SDNN (first quartile: < 60 msec; second quartile: > 60 and < 100 msec; third quartile: > 100 and <140 msec; and fourth quartile: >140 msec), progressive increase was found in VO_2max; and, SDNN was significantly linked with estimated VO_2max. **Conclusion:** In conclusion, the results of this study demonstrate that exercise training improves cardio-respiratory autonomic function (and increases heart rate variability). Improvement in cardio-respiratory autonomic function seems to translate into a lower rate of long term mortality. Ultra-short heart rate variability is a simple cardio-pulmonary fitness test which just requires 15 minutes, and involves no exercise such as in the treadmill or cycle test.

Key words: Exercise, fitness, heart rate variability, standard deviation of normal-to-normal QRS intervals

INTRODUCTION

Cardio-pulmonary fitness is related to the ability to perform large muscle, dynamic, moderate-to-high exercises for a prolonged period.[1] The performance of such exercises depends on the functional state of the cardiovascular, respiratory, and skeletal muscle systems. A variety of tests have been used to check cardio-pulmonary fitness and some of these tests are quite popular, such as, the Cooper 12-minute test.[1] The procedure of this test involves the participants running with maximal effort for 12 minutes exactly. The advantages of Cooper test are that the whole team can participate together, and compete against each other. The test is relatively easy to carry out, and does not involve too much time or equipment. It can also be used easily for training; and, any improvements can be easily appreciated. The disadvantages include that it is an indirect test, the results of which are not very accurate. Also, it is suitable only for well trained individuals due to the fact it requires maximal effort for the entire length of the test. Another disadvantage is that the test does not give actual maximum oxygen consumption values; it only gives a classification of poor to excellent. Hence, it has been suggested that this test is best for comparing athlete's individual scores against each other to monitor improvements, rather than comparing the scores of the whole team. In the laboratory, maximum oxygen consumption is the gold standard in the assessment of cardio-pulmonary fitness.[2]

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Normally, heart rate is controlled by autonomic nervous system activity.[3,4] Heart rate variability (HRV) refers to the beat-to-beat alterations in heart rate. HRV demonstrates a relationship between autonomic nervous system function (sympathetic or vagal activity) and cardiovascular system. On the other hand, HRV is a quantitative cardiovascular marker of autonomic activity.[5,6] Over the past decade, HRV has been recognized as a predictor of cardiovascular events, both in symptomatic and asymptomatic population.[3-6] Also, it was found that reduced HRV predicts hypertension[7] and hyperglycemia[8] in the future. HRV may be evaluated by a number of methods. The simplest variable is the standard deviation of normal-to-normal QRS intervals (SDNN) in a continuous electrogram (ECG) recording.[9] Traditionally, HRV is recorded over a longer period (24 hour); however, some investigators have reported that ultra-short HRV (2-15 minutes) is strongly correlated with the 24-hour HRV.[10,11]

It is known that exercise induces cardio-respiratory autonomic modulation. The aim of this study was to assess the cardio-pulmonary fitness by ultra-short HRV.

MATERIALS AND METHODS

Study population

Study population was divided into 3 groups: Group-1 (n = 40) consisted of military sports man who volunteered to participate in this study. Group-2 (n = 40) were healthy age-matched sedentary male subjects who had a normal BMI [BMI = 19-25 kg/m^2). Group-3 (n = 40) consisted of healthy age-matched obese male subjects [BMI > 29 kg/m^2). The third group was selected for calculating quartiles of HRV. All subjects were normotensive (blood pressure < 140/90 mmHg). The subjects of the research were all free of cardiovascular and pulmonary disease, alcohol use, and diabetes mellitus; and, were not taking any kind of medication, and did not present with any abnormal electrocardiographic patterns. Each subject provided informed written consent. The study was approved by the university ethics committee.

Ultra-short heart rate variability recording and analysis

Before the test, all the subjects rested in a supine position for a minimum of 15 minutes in a room with a constant temperature of 25 degree C. For the Holter recording, standard digital devices were used. Two leads (II and V1) were recorded over 15 minutes. SDNN was calculated by the device software.

Cardio-pulmonary fitness test

After Holter recording, Bruce protocol treadmill test was used. At timed stages during the run, the slope of the treadmill is increased as detailed in Table 1. The subjects run on a treadmill to exhaustion. Maximum oxygen consumption (VO_2max), which has been shown to be an objective criterion of cardiopulmonary fitness, was calculated by Foster equation:[12]

$$VO_{2max}\ (ml/kg/min) = 14.8 - [1.379 \times T] + [0.451 \times T^2] - [0.012 \times T^3]$$

'T' is the total time of the test expressed in minutes and fractions of a minute.

Statistical analysis

All values are presented as mean ± standard deviation (SD). Comparisons between groups were made using Student's *t*-test and Mann-Whitney U test as appropriate. For all analyses, P-value < 0.05 was considered significant.

RESULTS

Baseline characteristics

Table 2 shows baseline characteristics of the study population. The mean age was identical between 3 groups as might be expected from the matching.

Relation between standard deviation of normal-to-normal QRS intervals (SDNN) and maximum oxygen consumption (VO_{2max})

Relationship between SDNN and estimated VO_2max are demonstrated in Table 3.

Table 1: Bruce protocol treadmill test

Stage	Time (min)	km/hr	Slope (%)
1	0	2.74	10
2	3	4.02	12
3	6	5.47	14
4	9	6.76	16
5	12	8.05	18
6	15	8.85	20
7	18	9.65	22
8	21	10.46	24
9	24	11.26	26
10	27	12.07	28

The treadmill is set up with the stage 1 speed (2.74 km/hr) and grade of slope (10%) and the subjects commence the test. At the appropriate times during the test, the speed and slope of the treadmill are adjusted.

Table 2: Baseline characteristics of the 3 groups involved in the study

	Group-1 [Military sports man] (n = 40)	Group-2 [Healthy sedentary male] (n = 40)	Group-3 [Obese male] (n = 40)	*P* value		
				Group 1 versus 2	Group 1 versus 3	Group 2 versus 3
Age (years)	35.1 ± 7.9	37.4 ± 6.1	35.6 ± 3.2	NS	NS	NS
Body mass index (kg/m²)	21.5 ± 3.7	21.5 ± 2.3	32.2 ± 3.8	NS	0.012*	0.012*
Systolic blood pressure (mmHg)	122.3 ± 11.6	132.1 ± 18.2	132.3 ± 12.1	NS	NS	NS
Diastolic blood pressure (mmHg)	75.6 ± 10.3	75.2 ± 10.6	81.1 ± 10.1	NS	NS	NS

*Where, *significant difference; NS = Not significant.*

Table 3: Relation between standard deviation of normal-to-normal QRS intervals (SDNN) and maximum oxygen consumption (VO_{2max}) of the three groups involved in the study

	Group-1 [Military sports man] (*n* = 40)	Group-2 [Healthy sedentary male] (*n* = 40)	Group-3 [Obese male] (*n* = 40)	*P* value		
				Group 1 versus 2	Group 1 versus 3	Group 2 versus 3
SDNN (msec)	195.7 ± 11.5	122.3 ± 9.7	55.4 ± 9.2	0.003*	0.001*	0.003*
Estimated VO_{2max} (ml/kg/min)	50.2 ± 5.5	39.1 ± 5.6	30.5 ± 6.9	0.012*	< 0.001*	0.016*

*Where, *significant difference; SDNN = Standard deviation of normal-to-normal QRS intervals; VO_{2max} = Maximum oxygen consumption.*

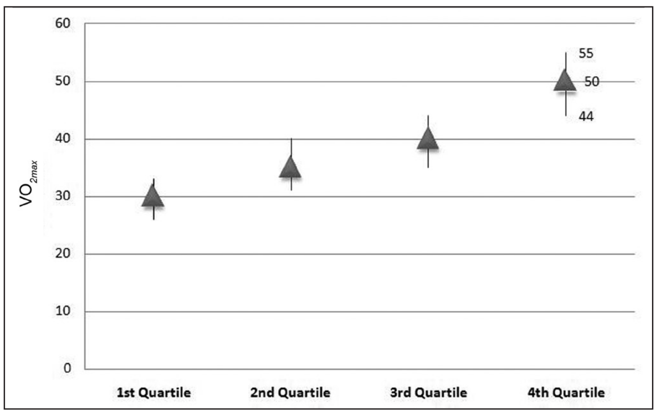

Figure 1: Maximum oxygen consumption (VO_{2max}) of study population compared by quartiles of standard deviation of normal-to-normal QRS intervals (SDNN). When the study population was divided into quartiles of SDNN (first quartile: < 60 msec; second quartile: > 60 and < 100 msec; third quartile: > 100 and <140 msec; and fourth quartile: >140 msec), progressive increase was found in VO_{2max}.

When the study population was divided into quartiles of SDNN (first quartile: < 60 msec; second quartile: > 60 and < 100 msec; third quartile: > 100 and <140 msec; and fourth quartile: >140 msec), progressive increase was found in VO_2max; and, SDNN was significantly linked with estimated VO_2max values [Figure 1].

DISCUSSION

Heart rate variability versus ultra-short heart rate variability recording

HRV may be evaluated by a number of methods. The simplest variable is SDNN in a continuous ECG recording.[9] Previously, 24 hour was determined as an optimal cut point for HRV recording and analysis. Bigger *et al.* found that measures of RR variability calculated from short (2 to 15 minutes) ECG recordings are remarkably similar to those calculated over 24 hours.[11] Their finding was supported by other researches.[10]

Ultra-short heart rate variability as a novel tool for cardio-pulmonary fitness test

HRV is a quantitative cardiovascular marker of autonomic activity. Over the past decade, HRV has been recognized as a predictor of cardiovascular events both in symptomatic and asymptomatic population.[3-6] It was also used in risk stratification for sudden cardiac death and diabetic autonomic neuropathy. Some investigators showed increasing interest regarding HRV in sport medicine and training sciences. They used HRV as a tool for noninvasive testing of autonomic nervous system activity with exercise training. They showed that regular exercises result in a significant improvement of all HRV indices.

In the present study, we have analyzed cardio-pulmonary fitness (VO_2max) and ultra-short HRV (SDNN). We found that SDNN is significantly linked with estimated VO_2max. We showed that SDNN is a simple cardio-pulmonary fitness test which just requires 15 minutes, and involves no exercise such as in the treadmill or cycle test.

CONCLUSION

In conclusion, the results of this study demonstrate that exercise training improves cardio-respiratory autonomic function (and increase heart rate variability). Improvement in cardio-respiratory autonomic function seems to translate into a lower rate of long term mortality. Ultra-short HRV is a simple cardio-pulmonary fitness test which just requires 15 minutes, and involves no exercise such as in the treadmill or cycle test.

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